PEDIATRIC CARDIOLOGY

Digital Subtraction Angiography in Patients With Transposition of the Great Arteries After Surgical Repair

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Digital subtraction angiography was used for postoperative evaluation of seven patients who underwent the Senning procedure for repair of d-transposition of the great arteries. Their ages ranged from 2.5 to 3 years. The patients were premedicated with methohexital (25 mg/kg rectally), and 0.3 to 0.4 ml/kg of diatrizoate was injected into a peripheral vein through a plastic needle. Images were obtained on a Technicare DR-960 or Diasonics DA 100 digital angiographic unit at four frames per second using 256 × 256 matrix and a 6 inch (15.24 cm) field size. In all patients, the venous systems, cardiac chambers and great arteries were well visualized. Two patients had obstruction of the superior vena cava with a dilated azygos vein draining into the inferior vena cava. One patient had severe obstruction of the left pulmonary artery.

Digital subtraction angiography is safe and easy to perform and appears to be a valuable alternative method for evaluating patients after surgical repair of transposition of the great arteries. The small amount of contrast material required and the low radiation dose make it attractive for use in children.

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Pulmonary venous or systemic vena caval obstruction is the most common complication of the intracardiac baffle procedure by either the Senning or Mustard procedure for d-transposition of the great arteries (1,2). Digital subtraction angiography has emerged as a less invasive alternative to conventional angiocardiography. This new technique can be used to evaluate the anatomy of the great arteries and intracardiac structures. With this modality, the cardiac structures can be studied by digital processing of fluoroscopic images of the heart with a lower radiation dose and a smaller volume of contrast agent than with cineangiography (3–8).

We used digital subtraction angiography for the postoperative evaluation of patients who underwent the Senning procedure for repair of d-transposition of the great arteries and report our preliminary experience with this new diagnostic modality.

Methods

Study patients. Seven patients aged 2.5 to 3 years were evaluated by digital subtraction angiography. Their body weight ranged from 12.5 to 15.2 kg. All patients had the Senning procedure during the first year of life for correction of d-transposition of the great arteries. Postoperative cardiac evaluation included history, physical examination, electrocardiogram and echocardiogram with the Doppler method.

Procedure. The patients were premedicated with methohexital (Brevital), 25 mg/kg rectally, and 0.3 to 0.4 ml/kg of diatrizoate (Renografin-76) was injected into an arm vein or jugular vein through an 18 or 20 gauge, 1.5 inch (3.8 cm) plastic needle at a rate of 3 to 5 ml/s. The digital images were obtained on a Technicare DR-960 or Diasonics DA-100 system at four frames per second using a 256 × 256 matrix and a 6 inch (15.24 cm) field size on the image intensifier. Radiographic settings were 65 to 75 kVp and 12 to 20 mA. In these digital systems, the analog signal was logarithmically amplified, passed through an analog to digital converter and placed in the image memory of the computer. All images were made in the radiographic mode. A Winchester disk was used for short-term storage, and magnetic digital tape was used for archival purposes.

Results

In all patients, the vena caval system, cardiac chambers, pulmonary venous system and great arteries were well visualized (Fig. 1 and 2). The atrioventricular and semilunar valves were not clearly seen. Five patients had widely patent venae cavae without any evidence of obstruction. The right

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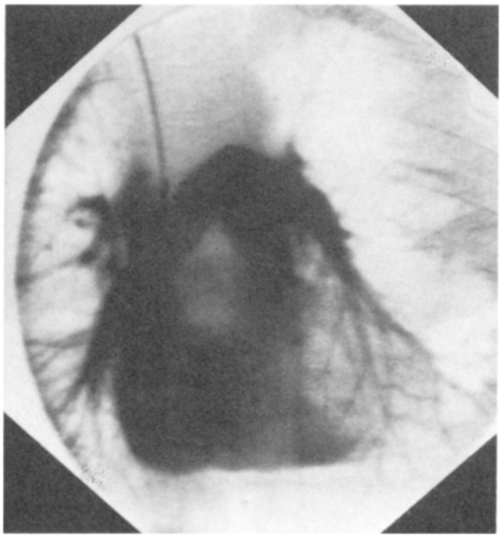

Figure 1. Injection of contrast agent into the superior vena cava outlines the normal right heart structures.

ventricular outflow tract and pulmonary artery systems were well outlined, and blood flow was distributed evenly to both lung fields (Fig. 3). Two patients had severe obstruction of the superior vena cava with a dilated azygos vein draining into the inferior vena cava (Fig. 4). The pulmonary venous systems and newly formed left atrium were adequately visualized (Fig. 5).

One patient had severe obstruction of the left pulmonary artery (Fig. 6, upper panel). On levophase, the right pulmonary vein was visualized; however, no pulmonary venous return was evident from the left lung, confirming complete obstruction of the left pulmonary artery (Fig. 6, lower panel). This patient had chronic respiratory problems after the Senning operation. Postoperative cardiac catheterization revealed complete obstruction of the left pulmonary artery, presumably due to a previous pulmonary embolus.

Discussion

Value of digital subtraction angiography. Digital subtraction angiography has been considered as a valuable technique for the evaluation of the great arteries, intracardiac structures, cardiac function and shunt lesions (3,9–11). It is an excellent method for visualizing the great arteries and vena caval and pulmonary venous systems, which are not readily visualized by two-dimensional echocardiography. Moreover, digital subtraction angiography provides information similar to that obtained from conventional angiographic studies using one-half to one-third the amount of contrast material required for conventional angiography, and the contrast agent can be injected either centrally or peripherally. It is particularly helpful in the postoperative evaluation of the adequacy of anatomic repair because the major venous entry for cardiac catheterization is often impaired owing to vena caval blockage from previous procedures.

Postoperative complications. The most common anatomic complication of the intracardiac baffle procedure for d-transposition of the great arteries is pulmonary or systemic venous pathway obstruction. Supraventricular arrhythmia, tricuspid regurgitation and right or systemic ventricular dysfunction have also been known as functional complications after this procedure.

Comparison with other imaging modalities. Systemic and pulmonary venous pathways have been extensively evaluated by two-dimensional and pulsed Doppler echocardiography and radionuclide imaging (12–15). All these techniques have some drawbacks. The echocardiogram has superb spatial resolution to identify anatomic detail, but its tomographic nature gives restricted views, especially of

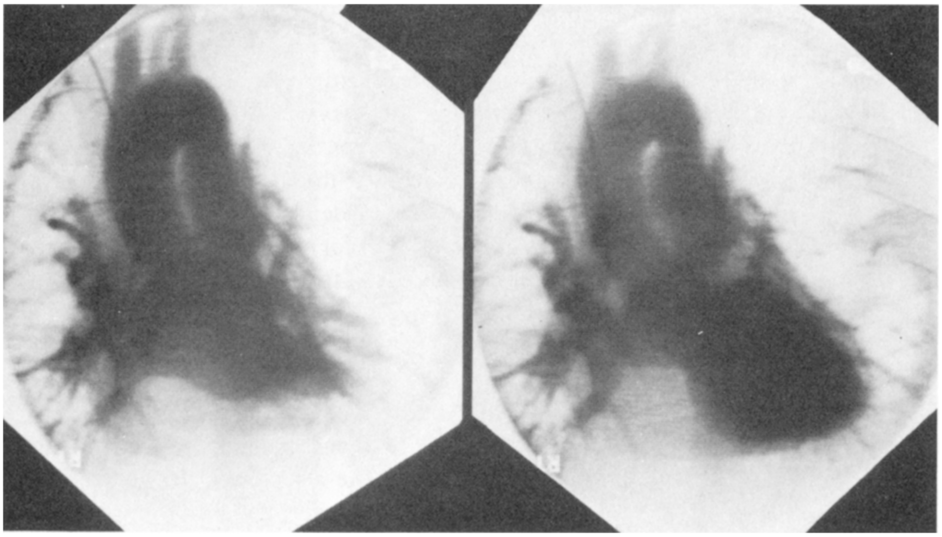

Figure 2. On levophase, normal pulmonary venous drainage into the left atrium (**left**) and the left ventricle and aortic arch (**right**) are well visualized.

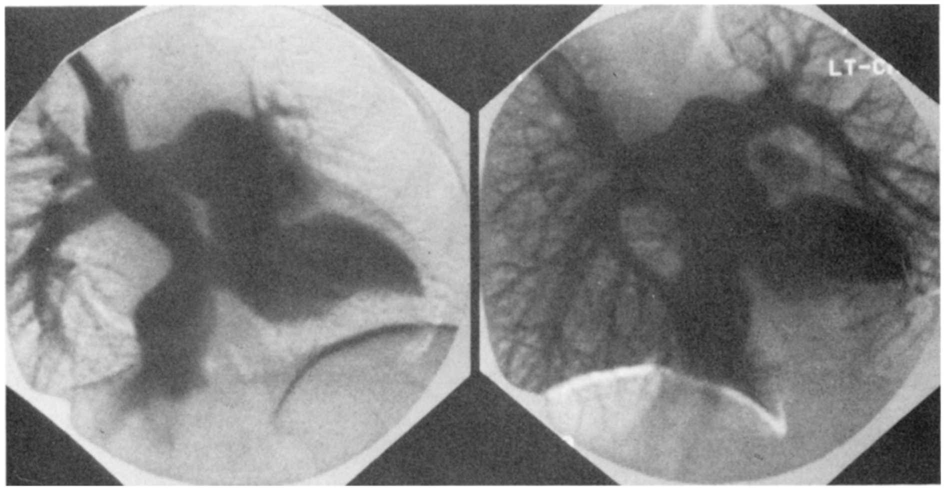

Figure 3. Digital images from a 2½ year old child after surgical repair. Imaging after a 6 ml injection of Renografin-76 into the antecubital vein shows a widely patent vena caval system, venous atrium, venous ventricle and pulmonary arteries in anteroposterior (**left**) and angled (**right**) views.

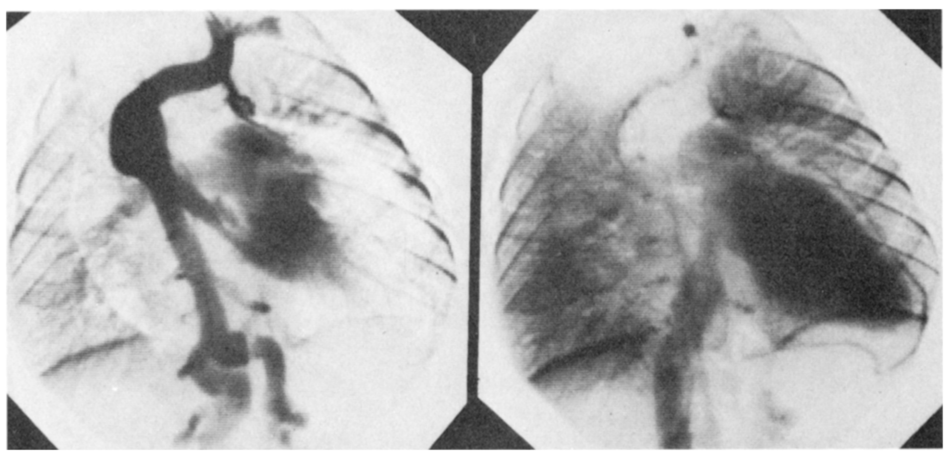

Figure 4. Digital angiograms obtained from a 2½ year old child 2 years after the Senning operation. Imaging after injection into the antecubital vein demonstrates severe obstruction of the superior vena cava at the junction with the right atrium and dilated azygos system (**left**). A later frame (**right**) shows filling of the inferior vena cava through an azygos vein.

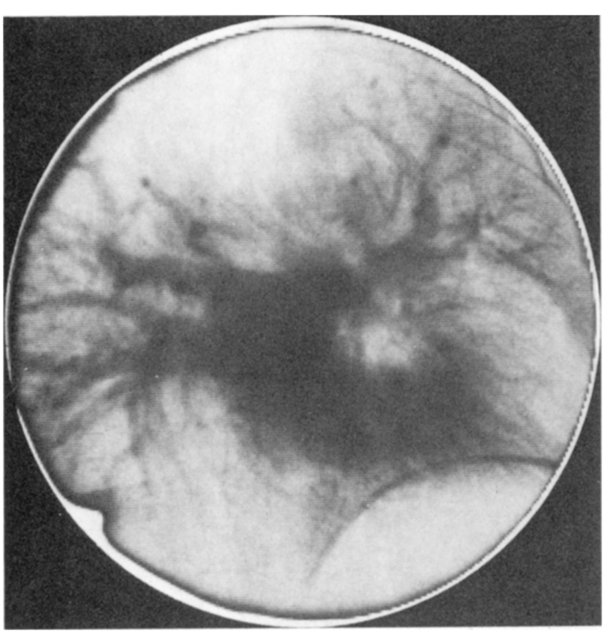

Figure 5. Injection of contrast agent into the antecubital vein in a 3 year old child after surgical repair reveals normal pulmonary venous return into the newly formed left atrium.

structures outside the cardiac chambers. Nuclear imaging is a sensitive detector of physiologic data, but it gives suboptimal spatial orientation and limited anatomic detail. In contrast, digital subtraction angiography provides efficient use of X rays by using a fluoroscopic imaging chain (image intensifier and high resolution television camera), logarithmic amplification of the signal and temporal mask mode subtraction resulting in excellent quality images. The conversion of the analog signal into digital form is vital for the study of the cardiovascular system because it permits enhancement of images with a lesser amount of contrast material and radiation exposure (4,5,8,16). By eliminating much of the cineangiographic part of cardiac catheterization, digital subtraction angiography should decrease the risks associated with conventional angiography in small infants.

Amount of contrast medium. Our current study indicates that digital subtraction angiography can be applied successfully in the diagnosis of venous pathways in children after surgical repair of d-transposition of the great arteries. With injections made peripherally, we were able to greatly reduce the volume of contrast material and the radiation dose, compared with those required in conventional angi-

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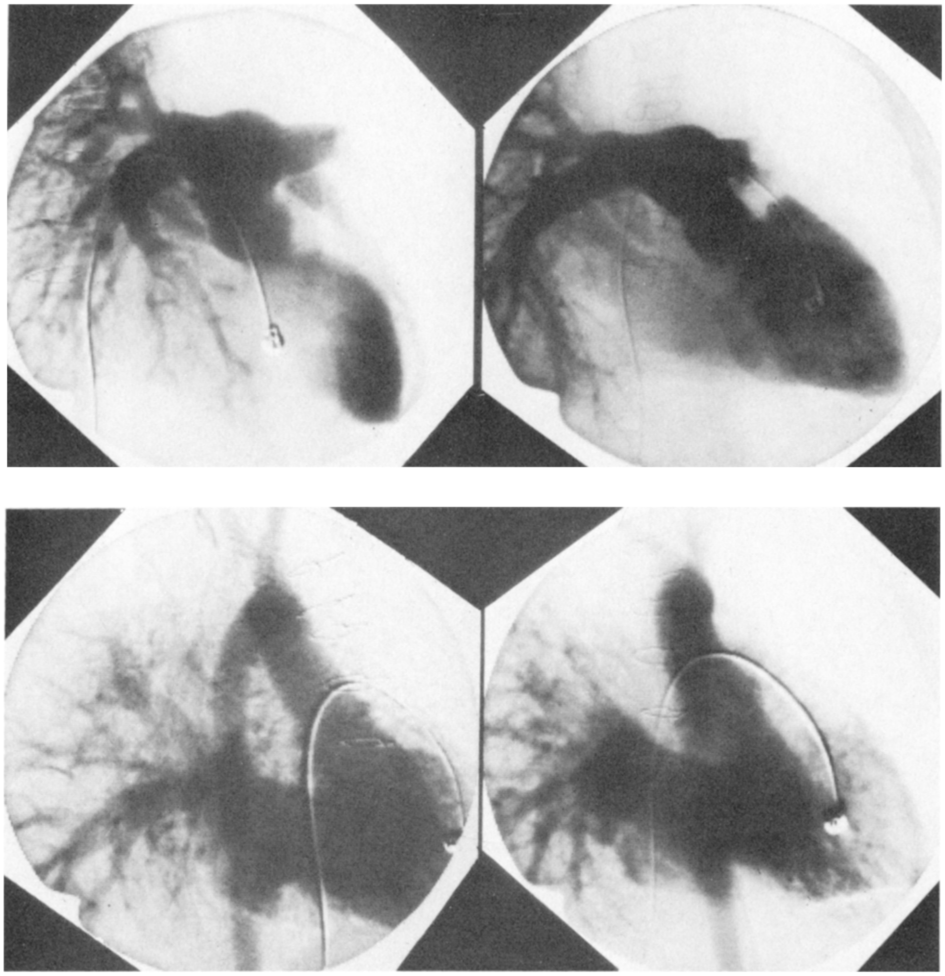

Figure 6. Upper panel, Digital angiogram in this 3 year old child shows complete occlusion of the left pulmonary artery on anteroposterior (**right**) and angled (**left**) views. **Lower panel**, On levophase, the right pulmonary veins are visualized; however, no pulmonary venous return is evident from the left lung.

ography, without loss of diagnostic information. The reduction of contrast material with digital subtraction angiography is a major advantage in pediatric patients. The undesirable dose-related side effects of contrast material in small children are well known, especially in those neonates with cyanotic heart lesions or congestive heart failure. Injections of 1.0 or 1.5 ml/kg of contrast material have been associated with a rapid decline in pH which can induce arrhythmias and poor cardiac function. A rapid increase in osmolarity may result in pulmonary edema and impairment of renal function.

Recent experiences suggest that optimal visualization of great arteries and veins by digital subtraction angiography with a small amount of contrast material can be achieved. Furthermore, when lesions are complex and more angiographic views are needed for accurate diagnosis, multiple angiograms can be obtained with digital subtraction angiography without exceeding the volume limit of contrast material.

Radiation exposure. In addition to the amount of contrast material, the major advantage of digital subtraction angiography is marked reduction of radiation exposure to the patient and angiographer. The recent report by Levin et al. (3) indicated that one can perform digital angiogram with approximately 4 to 10% of the radiation exposure rate required for cut-film angiography of cineangiography. In our laboratory, by utilizing the radiographic mode, radiation exposure to the patient was approximately half that of the conventional cineangiogram.

Conclusions. Our experience suggests that digital subtraction angiography can provide similar anatomic information equivalent to cut-film or cineangiographic technique. It is particularly important in the pediatric population since digital subtraction angiography requires a substantially lesser amount of contrast material and radiation exposure to the patient compared with conventional angiographic methods. With advancing technology and accumulation of experiences with digital subtraction angiography, it appears that this technique should be an invaluable part of a pediatric cardiac catheterization laboratory.

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